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VOLATILITY EFFECT ON EMPLOYMENT OPTION PRICING

Comparison between Black-Scholes and market value

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TUTKIMUKSEN TAVOITTEET

Tutkimuksen tavoitteena oli selvittää kumpi volatiliteetti, historiallinen keskiarvo vai markkinainformaatiosta johtamalla saatu ns. implisiittinen volatiliteetti, on parempi estimoitaessa työsuhdeoptioiden hintaa. Teoreettisen hinnan määrittämisessä on käytetty tunnettua Black-Scholes optioiden hinnoittelumallia. Markkinahintaa verrataan teoreettiseen hintaan joka on laskettu käyttämällä sekä historiallista keskiarvovolatiliteettia ja implisiittittistä volatiliteettia. Eri volatiliteettien kykyä ennustaa työsuhdeoption hintaa on mallinnettu regressiomallin avulla. Selitettävänä tekijänä mallissa on markkinahinnan ja teoreettisen arvon suhdeluku. Selittävinä tekijöinä on aika option maturiteettiin, option markkinahinta ja option absoluuttinen arvo eli onko option lunastushinta osakkeen markkinahintaa alhaisempi. Absoluuttista arvoa mitataan kahdella eri tekijällä. Suomen markkinoiden erikoisuus on mahdollisuus listata työsuhdeoptiot Helsingin Pörssiin. Tämä mahdollistaa vertailun markkinanhintojen ja teoreettisten hintojen välillä.

LÄHDEAINEISTO

Tutkimuksessa käytettiin Helsingin Pörssin osakkeiden päivätuottoja vuosilta 1997-2002 ja työsuhde ja osto-optioiden markkinahintoja 10. –13.12.2003. Riskittömänä korkona on käytetty 12 kuukauden Euribor keskiarvoa vuosilta 2000-2002.

TULOKSET

Historiallista keskiarvovolatiteettia käyttämällä poikkesivat työsuhdeoptioiden teoreettiset hinnat markkinahinnoista enemmän kuin käytettäessä implisiittistä volatiliteettia. Käytettäessä historiallista keskiarvovolatiliteettia 80 prosenttia teoreettisista arvoista olivat korkeammat kuin markkinahinta. Keskimäärin teoreettiset arvot olivat 45,3 prosenttia korkeammat. Käytettäessä implisiittistä volatiliteettia 70,6 prosenttia teoreettisista arvoista olivat suurempia kuin markkinahinnat. Huomattavaa kuitenkin on se, että keskimäärin teoreettiset arvot olivat enää vain 26,2 prosenttia korkeammat aiempaan 45,3 prosenttiin verrattuna.

AVAINSANAT

Työsuhdeoptio, implisiittinen volatiliteetti, historiallinen volatiliteetti, Black-Scholes kaava

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Abstract
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PURPOSE OF THE STUDY

The objective of this study is to find what volatility measures give reliable results when comparing theoretical employment option (ESO) values to the market values, historical or implied volatilities. Theoretical ESO values are calculated using Black-Scholes formula. The effectiveness of the volatility measures is determined using regression analysis with market to Black-Scholes ratio as dependent variable and options time to maturity, option's market value, in/out-of-the-money factor and share minus strike price as explaining variables. The unique feature that ESO's are listed in the Helsinki Stock Exchange (HEX) enables us to make the comparison between market and theoretical values.

DATA

The data in this study comprises of the daily lognormal stock returns between years 1997-2002 retrieved from the HEX and market data of employment options and call option prices retrieved from HEX and EUREX (Eurex is the world's largest futures and options exchange and is jointly operated by Deutsche Börse AG and SWX Swiss Exchange) between dates 10. - 13.12.2003. The risk-free rate used in the calculations has been derived using average 12-month Euribor interest rate during 2000-2002.

RESULTS

The main finding of this study is that using historical share volatilities to predict future volatilities causes heavy over pricing compared to market values. 80 percent of the options in this study were over priced compared to market values when historical share volatilities were used. The average over pricing was hefty 45,3 percent. When average implied volatilities were used the percentage of over priced options fell by almost 10 per cent to 70,6 percent but still remained very high. More importantly, the average over pricing fell from 45,3 to 26,2 percent that represents almost 20 percent decrease.

KEYWORDS

Employment option, implied volatility, historical volatility, Black-Scholes formula

1 Introduction

Using employment stock options (ESO's) to motivate managers to increase share value and thus increase the wealth of the shareholders is widely used in most of largest Finnish companies. In Finland the popularity of ESO's increased in the 90's when shareholders began to demand higher return on invested capital. The unique feature in the Finnish market is that companies can have their ESO's listed in the Helsinki Stock Exchange and get continuous price quote on their ESO. This enables us to compare ESOs' theoretical and market values. Black-Scholes formula is widely used in estimating option values. The formula is fairly straightforward to use but the volatility that is inputted affects to outcome greatly. The volatility used in theoretical formulas is examined in this study. In chapters 2 and 3 the current situation of option compensation in Finland and the reasons behind option compensation are discussed. One valuation method used to value stock based compensation plans are covered in the chapter 4. Historical and implied volatilities are handled in chapter 5. The empirical parts of the study starts in the chapter 6 were the Finnish data is examined. Results of the study and conclusions are disclosed in chapters 7 and 8.

1.1 Previous research

This subject has been studied a lot mainly in the US markets but also in Finland. Lisa K. Meulbroek has examined the efficiency of equity-linked compensation using US data (Financial Management, 2001). Her paper studies employment stock options (Herein after called ESO) of the all NYSE, AMEX and NASDAQ firms listed as of December 31, 1998, examining separately the results for a sample of Internet-based firms defined by the Hambrecht & Quist (H&Q) Internet Index.[1] The paper derives a method to measure deadweight cost. Deadweight cost measures the ratio of ESO's value to employee to ESO's theoretical market value. The idea is that managers require larger return than undiversified investors to their ESOs. Meulbroek has used the Sharpe ratio in order to find out what expected return would an undiversified manager require to be indifferent between holding option/stock *j* in a single stock portfolio, and holding a market portfolio levered to firm *j*'s volatility.
Meulbroek has found that the deadweight cost of equity-linked compensation plans in the USA is very large ranging from the average of 50 per cent (Internet firms) to average of 70 per cent (NYSE firms).

In Finland Ikäheimo, Walden and Immonen studied the taxation efficiency of option plans in the Finnish system. They came up with efficiency ratio which measures the ratio between actual net benefit of option to the employee after taxes and the amount that shareholders' well-being is transferred to the employees in form of options. The idea behind it is that the shareholders pay most of the option plan granted to employees but when an employee exercises the option and receives the benefit he has to pay taxes for it and thus he does not receive the whole benefit himself. Also similar efficiency ratio was calculated for synthetic options.

[1] The H&Q Internet Index comprises a sub-sample of Internet-based firms, and is not confined to H&Q clients. The Internet Index is widely cited and viewed as a reliable reflection of Internet-based activity.

The efficiency ratio with regular ESO is 61,5 per cent and with synthetic options 121,5 per cent. The reason for so large difference is that synthetic option accumulates pension where as regular ESO does not. Ikäheimo, Walden and Immonen sum their study up by saying that the current taxation system favours synthetic options and that the system does not support the original idea of binding employees more closely to the firm by granting them ESOs.

In 2003 Ikäheimo, Kuosa and Puttonen made a study, which examines stock option valuation methods in the major accounting standards. The standards included were Statement of Financial Accounting Standard 123 (SFAS No. 123) and International Financial Reporting Standard (IFRS). Both of these models rely heavily on the Black-Scholes model. They found that when ESO quatations are compared to their Black-Scholes values, the average underpricing is 15,5 per cent and the median underpricing varies between 1,4 per cent and 54,2 per cent. Based on these findings they suggest that the valuation ESOs should be considerably lower than FAS No. 123 and IFRS proposals suggest.

1.2 Objective of the study

In order to get the full potential out of compensation it is significant that the employee who receives the compensation values it. Otherwise the effort and money spent in compensation program is not effectively used. The shareholders pay equity-linked compensation programs and it is therefore in their best interests to get fair return on their investment.

Unique feature in the Finnish markets is that ESO's can be listed to the Helsinki Stock Exchange (HEX). This provides a possibility to compare the theoretical and actual market values of ESO's. According to previous studies the market value seems to be lower than the theoretical value of ESO's. The Black-Scholes formula is widely used in the option valuation for its ease of use. Most of the inputs needed for the formula are objective but the volatility used plays significant role in option value and it is not straightforwardly determined.

The objective of this study is to find what volatility measures give reliable results when comparing theoretical employment option values to the market values, historical or implied volatilities. Ratio of market to theoretical Black-Scholes value is calculated using average historical volatility and average implied volatility as an input to the Black-Scholes formula. Using regression analyses I try to find out which one of the above mentioned two ratios are better explained. In regression analysis dependent factors are market to Black-Scholes ratios (B-S value calculated using average historical volatility calculated from daily returns from 1997 to 2002 and average implied volatility deduced form the market data). Options time to maturity, option's market value, in/out-of-the-money factor and share minus strike price are the explaining variables. Results should disclose which ratio is better explained using above described variables, the one using average historical volatilities as an input to Black-Scholes formula or the one using average implied volatility as an input to Black-Scholes formula. The data is collected from the 15 largest Finnish companies (by turnover) that are listed and have equity- linked compensation plan listed in the Helsinki Stock Exchange.

2 Employee compensation in Finland

2.1 Definition

Previously employees' payroll has been linked with the input s/he has contributed. Nowadays this correlation is not so straightforward. Results are more significant when defining the compensation, not the time consumed to achieve the results. According to Sedig (1994) proper compensation system ensures the employee with best net salary and the employer with motivated, committed and reasonably priced personnel. Well-organised compensation system should be easily monitored and it should prevent oversize compensation. Agency theory approach says that compensation should be planned in a way that it diversifies the risks between employees and shareholders (Copeland – Weston, 1992). With compensation systems the shareholders try to minimise the agent costs, which occur when objects of shareholders and management (employees) differ. When both employees' and shareholders share the same objects the former problem mitigates.

Giving employees options and thus making them interested in the development of the company's stock price is one way to motivate employees. It has been studied that when the employees have gained 1 million from their options at the same time the shareholders have gained 100-150 million (Helaniemi-Helaniemi, 1995). For this reason it is no wonder that stock option plans have been very popular among shareholders in both larger and smaller companies.

Stock option plans are off-balance sheet items (excluding synthetic options) and thus are disclosed only in the additions to financial statements. Current shareholders hand over part of their wealth to employees when the exercise price of the option is lower than the market price. This effect is called dilution effect and it can be prevailed with synthetic option arrangement or by using company shares (own or other company shares). The motivation effect should be larger than the dilution effect in order to make the compensation profitable to the shareholders.

If there is no clause in the contract between the employee and the employer the employee does not have to buy the shares underlying in the option. S/he can sell the right to buy the shares to a third person. This of course does not support the original idea of binding the employee to the company via stock ownership. In addition this might harm the market value of the shares when more company's stock becomes available. To prevent these kinds of situations some limitations concerning selling of the options can be made to the contract between employer ant the employee. However these limitations shall be in line with Finnish law for limited companies and is valid only between the two parties.

As following example clarifies, it is not an easy task to build up an effective compensation system. The example is published in the Journal of Financial Economics in 1999.

Under Ralston Purina Company's 1986 incentive contract 14 managers would receive $49.1 million in stock if within ten years the stock price closed above$100 for ten consecutive days. While the contract required a 57.8 % increase in stock price, it did not motivate managers to create value because the rate of return required to reach $100 in ten years was substantially less than Ralston's cost of equity capital at the time of contract's adoption. Barring any action by managers that would substantially change the market's expectations about the firm, reaching $100 hurdle price would be easy. In fact, managers collected the contracts payoffs within five years despite an industry-adjusted loss of $2.1 billion in shareholder value.

On the surface, Ralston's contract appears to provide managers with incentives for value creation because it requires a stock price increase of 57.8% to earn the restricted shares. However, an analysis of the contract's features reveals that its *payoffs do not require value creation by managers. With an adoption-day stock price of $63,375, the implied annually compounded capital gain required to reach $100 ex-dividend hurdle price in exactly ten years is only 4.67%. Adjusting for Ralston's 1982-1986 average annual dividend yield 3.1% leads to an annual return of only 7.77%. At the time of the contract's adoption, the risk free rate was 7.5%. More importantly, using the capital asset pricing model with a market risk premium of 7.5%, the risk-free rate of 7.5% and Ralston's beta of 0.96 yields an estimate of 14.7% for Ralston's annual cost of equity capital on the contract's adoption date. Adjusting for Ralston's 3.1% historical dividend yield results in a dividend-adjusted cost of equity capital of 11.6%. At this rate and using annual compounding, the expected stock price ten years from the contract's adoption date is $189.92. Thus, if the hurdle price is met in exactly ten years, managers could actually destroy $89,92 per share of shareholder value and still receive the contract's payoffs.*

2.2 Agency relationship

There are three parties involved when corporate compensation is considered. The first party is the company which is paying the compensation. It is in the company's best interest to have the most motivated and capable employees in its payroll. When deciding how to attract employees to work for the company there are two key questions the organization has to ask when formulating reward strategies and policies:

1. How much should be paid to each employee?
2. What form should that payment take?

A range of alternative payment systems and methods of determining the pay levels are available to help managers answer these questions in the best interest of their organization. In answering the first there is a need to consider relative merits of paying at or above market levels, using some form of job evaluation scheme, and bargaining with recognised trade unions. In answering the second question there is a greater number of alternative systems to consider ranging from traditional time-based rates to options etc.

The second party is the employee who off course is interested in getting the maximum compensation in return for his contribution. The third party consists of shareholders. They require that their investment to the company yield best possible interest. Jensen and Mecklin have defined agency relationship as follows

> *A contract under which one or more persons (the principal(s)) engage another person (the agent) to perform some service on their behalf which involves delegating some decision making authority to the agent.*

According to agency theory the shareholder (the principal) gives the manager (the agent) the authority to run the business in best possible way. The result of agent's activities belongs to the principal and the agent gets paid for its services. The model suggests that the result is a product of two factors[2]:

$x = X(a, s)$, where x = results (1)
a = level of agent's activity
s = state of environment

The state of environment signifies all the factors to what the agent cannot affect with its activity. Presumption in the model is that the higher the level of agent's activity the higher the results. Another presumption is that the agent is job averse, meaning that agent rather maximizes his own than principal's benefit.
Two widely known concepts are linked to agency theory, namely *moral hazard* and *adverse selection.*

[2] Based on articles by Harris and Raviv 1978, Shavell 1979

The moral hazard or hidden action problem signifies a situation where the agent selects an option that maximizes his but not principals benefit and the client cannot detect the chosen course of action. One example of such problem is situation where the manager of a large multinational company sets out to project that destroys shareholder value. The shareholder cannot be aware whether such actions are necessary or not and therefore the manager destroys shareholder value with out shareholder being aware of it.

The adverse selection or hidden information problem occurs when the agent chooses a course of action based on information which is exclusively in his attention and harmful to the principal. As oppose to moral hazard the principal can now detect the chosen course of action but is unaware whether this has been the right choice. The agent can make better ex ante valuation of the environment than the principal ex post when the action has taken place.

2.3 Equity compensation

Personnel share issue refers to rights offering which is solely directed to employees. These were popular in Finland in the late 80's. Before 1987 the benefit to the employee was considered tax-free but after that year the taxation was radically changed and the benefit was no more tax exempt. In 1988 the legislation was altered and the benefit was tax-free up to point where the exercise price was 15 per cent below the market price. This was again altered in 1993 to maximum of 10 per cent under the market price. This meant that the part of the benefit, which exceeds this 10 per cent limit, is taxed at ordinary rates. In addition to the 10 per cent rule described above the issue must concern the majority of personnel or otherwise the whole benefit is taxed at ordinary rates (TVL 66:1§). The majority of personnel are more than 50 per cent of the employees. If the company forms a concern it is not clearly stated in the law should the majority be calculated just from the issuing company or the whole group (Niskakangas, 2000).

The majority rule is the only restriction and thus the management can have a right to buy more shares than the employees.

When personnel share issue is concerned, the law is more extensive compared to normal employee-employer relationship used in civil courts. This more extensive approach covers also the previous employees if the perk relates to previous employment of the employee (Kiuru, 1999). This conception covers both options and personnel share issues. If the beneficiary is member of the board of directors his benefit is taxable even though there is no employment relationship in the meaning described in the employment law (TSL). Liability to taxation concerns not only the employer company but all subscription rights belonging to the same group. For example, the management of the parent company is liable to pay taxes if they have right to subscribe the shares of the subsidiary by more than 10% discount. The size of discount depends how the current value of the shares are defined. According to Finnish income tax law (TVL 66.2§) current price of publicly traded share is average trading price from the preceding fiscal year. If the average quote price during the following month after the share is first quoted is lower than the current price defined in taxation, the lower price is then used in defining the size of the benefit. This has to be done in order to take the dilution into account. For example if the personnel share issue is carried out alongside common share issue the number of new shares increases and causes share price to drop. This rule also prevents the disadvantageous situation where serious drop in the share price after the share issue leads to situation where the subscriber is not even capable to pay the income tax caused from the sale of shares.

Provided that the personnel share issue includes a right to subscribe company shares (free or at discount) in future, this benefit is considered to be taxable income. However, if this benefit is offered also to other shareholders the benefit is taxed at capital gains rates.

When the shares subscribed in personnel share issue are reassigned the income tax paid is included in acquisition costs. This is done to avoid double taxation since the subscriber has already paid taxes when s/he has received the shares. The possible gain realised when reassigning the shares is taxed at capital gains rates. It is also possible for natural person to use so-called "acquisition cost assumption". When using this method the person is not allowed to make any deductions and potential the losses are tax deductible from capital gains.

The right to subscribe shares in personnel share issue is liable to withholding tax. This means that the subscriber has to pay both the exercise price and the tax. However, tax paid does not accumulate employee's pension and thus s/he does not have to pay pension insurance payments. Since the shares are subscribed in rights issue, not reassigned, they are exempt of capital import tax.

The taxation of the issuer (the company) concerning personnel share issues is pretty straightforward. The assets gained from share issue are invested in restricted shareholders' equity and they are not liable to income tax (EVL 6§). Also the difference between market and subscription price is not deductible expense since by rights the company does not pay anything in share issue, the payers are the shareholders. Naturally the social security payments occurred from the share issue is deductible in taxation. The employer is liable to withhold the income tax on employee's behalf.

2.4 Option compensation

Ikäheimo, Walden and Immonen[3] have studied the Finnish option system and they have found two types of options. The first is *regular option arrangement* where the employee has the right to buy company shares at predetermined price after certain time. The second is so called *synthetic option*. In synthetic option

[3] Ikäheimo – Immonen – Walden 2001

employee's salary is tied to stock performance and when the option matures and the stock price exceeds the exercise price the difference is paid to the employee as a regular salary. This way the synthetic option only imitates regular options and requires much more liquidity from the company point of view.

2.4.1 Regular options

According to Finnish law employment option is defined as a right to buy company stocks at predetermined price (at lower price than the market price when exercised). This right can be in a form of convertible bond, option loan, option right or other similar contract. (TVL 66.3 §)
Since 1995 the option income has been taxed as salary. The grounds for this kind of treatment were to cut the benefits of management and employee compensation (Ikäheimo et al. 2001). When the Finnish government made their proposal to change the option taxation they saw option income to be deferred salary and thus it should be taxed as salary, not as capital gain.

It is important to distinguish employee stock options (ESOs) from traded stock options (TSOs). While the exercise of a TSO does not affect the welfare of holders of the underlying stock, the exercise of an ESO is dilutive since the corporation issues new stock to the optionee. Thus, ESOs are type of warrant. While TSOs usually mature within one year of the date of issue, ESOs may be exercised in a window of time that extends over many years. (Huddart, 1994)

The notion of employee option is intentionally extensive. If the employee has right to buy shares of another company s/he works for these shares are considered to be employee options if this perk is based on employment. If the company forms a group the option can be on any of these companies' shares and it still is considered as an employment option. Also the stock can be listed or unlisted. (TVL 66.3 §)

In taxation the time of exercise is considered to be the point of time when person liable to pay taxes receives (with or without contribution) the underlying assets. From taxation point of view the reassignment of option rights to a third party is parallel to exercising of the options. Notable feature is that donation of the option rights to a third party is not considered to be parallel to exercise of the options and thus no taxes have to be paid at that moment. However, when the donee uses these option rights the benefit is considered to be donator's income and thus the donator is taxed. There is considerable tax risk embedded when using the option rights. This is derived from the fact that income is considered to be realized to the subscribers account at the moment the options are exercised. In reality this is not the fact since the shares are not immediately available for sale after the option is exercised. If the share price drops significantly during this period it may be that the profit from the sell of shares is not even enough to cover the paid exercise price for the option and taxes.

The legislation concerning stock options is in the Finnish law on earned income 66.3§. In principle, the possible benefit from the stock option plan should be taxed at the date of issuance of such grant if it is possible. In reality this is not so straightforward and thus there is dispute between legislators on what should be the fair value of the stock option. For this reason the taxation of the possible gain is postponed to the time of exercise of the option. First, the options are exercised in the money for taxable gain of $S_e - X$ and then the shares are sold for an additional taxable profit of $S_t - S_e$. [4]

When the option is exercised the company is subject to social security payments but not to pension fund payments. The taxation and accounting consequences for the Finnish stock option plans are summarised as follows:

[4] S_e = share price at the time of option exercise S_t = share price when selling the stocks acquired with option

X = exercise price

	Date of exercise (e)	Share selling date (t)
Company	Social security payments	No consequences
Employee	Income tax on: S(e) - X	Capital gains tax on: S(t) - S(e)

Table 2.1. Tax consequences of employment options to employee and the com-company.

For listed companies the current share price at the time of exercise is calculated as an average price on stock during the exercise day. If the company is unlisted the mathematical value of the stock is used as a measure of current value.

The benefit from the option is realized to the owner in the year when the option is exercised or the option right sold. No matter if the option is exercised or the rights sold, the tax burden is the same. This causes liquidity problem if the owner of the option rights decides to buy the shares. Without additional financing the employee can only purchase the following amount of shares (Ikäheimo et al. 2001):

$$q = \frac{m(1-v)(S-X)}{S} \quad (2)$$

where m is the maximum amount of shares available for exercise, v the tax on salary, S the current share price and the X the exercise price. The amount available for exercise depends on the relation between S/X and the tax percentage on salary. This problem has caused many option owners to sell the rights and not to buy the shares.

If the accumulated taxes the employee pays during the year is not enough to cover the taxes occurred from the option an additional tax is collected. Even though the capital gains from the option are taxed as regular salary, no pension or unemployment claims have to be paid. This also means that this salary is ignored when the pension is defined for the employee when s/he retires.

The profit on sale is taxed at capital gain rates when the employee sells the shares acquired based on the employment option. The part of the income taxed at ordinary rates and the price paid for the option right is added to the acquisition costs. This is done to prevent double taxation. It is also possible to use "acquisition cost method" when defining the size of taxable income. The possible losses incurred from the sale of the shares are possible to deduct from the capital gains within three years since the losses have occurred. The Finnish Supreme Court has ruled in its decision (1997:33) that losses occurred from the sales loss or expiration of the employment option is deductible as allowable expenses. The preceding situation is possible when the employee has paid compensation for the option, the option has been sold at a loss or the option has expired worthless.

The benefit gained by using employment options is taxed at ordinary rates. As with personnel share issues the taxes paid from the employment options do not include pension insurance payments nor unemployment payments. This is mainly because benefit accrues in the equity market and it is not connected to company performance (Eläketurvakeskus, 1994).

The company is liable to collect the taxes occurred on behalf of the employee. If the withholding tax is not enough to cover the occurred taxes fully, it is possible to pay the deficit in advance. The withholding tax can naturally not exceed the wage income earned by the employee. Since the option income is under withholding tax it leads that the usage of options usually emphasizes at year-end. If the benefit from the options is large enough it may be that the year-end salary goes covering the taxes. For this reason the employee has to sell the shares or the option rights in order to pay the taxes.

2.4.2 Synthetic options

In contrast to regular employment option the employee does not receive any shares of stock of the company. The employee's compensation is tied to share appreciation. In synthetic option plan the option holder does not become shareholder when the options are exercised. The option holder has hypothetical right to buy certain amount of shares at predetermined price. However, the employee cannot subscribe the shares but is paid the potential difference between the current market price and exercise price as salary. This salary is then taxed at ordinary rates and is subject to withholding tax. Since the benefit from the synthetic option is regarded as regular salary the beneficiary has to pay all the taxes related to regular salary. These include both unemployment insurance premium and retirement allowance. Although the synthetic option is taxed more heavily it also accumulates pension.

Synthetic options do not create new shares to the market and thus dilution is non-existent. Also, share capital does not increase and thus the board of directors do not need an authorization from the annual meeting to carry out synthetic option plan. All expenses are disclosed in that year's income statement the options have been exercised. The expenses are tax deductible and subject to all social insurance premiums including unemployment premium and pension allowance. The employer is liable to carry out the withholding tax on employee's behalf.

The firm has to pay different overhead costs when synthetic option is exercised. Social security premiums are divided into three payment classes depending on the size of the company. Group life insurance and accident insurance payments also vary depending on the size of the company. The unemployment insurance payment was in year 2003 0,8% of the salary expenditure (whole company) up to one million Euro and 3,1% from the amount of the salary expenditure exceeding one million.

Since the employer is liable to pay for the pension and unemployment premiums the exercise of synthetic option also accumulates pension, which means that the withholding tax is larger than it is with traditional employment options. Nevertheless, this makes it possible for the beneficiary to accumulate abnormally high pension as s/he reaches retirement age.

From the employer's side the synthetic option is favourable way to compensate the employees' since it can deduct all the expenses in taxation. However, synthetic arrangement requires liquidity since the whole benefit is paid out in cash and also pension premiums are to be paid. This makes synthetic arrangement favourable to solvent companies with plenty of cash. In addition synthetic arrangement is more flexible to carry out since the decision can be made without annual meetings approval. Synthetic options are widely used in Swedish companies. The Finnish-Swedish Stora Enso uses synthetic options in their compensation plans.

One disadvantage with synthetic option arrangement is that the original idea of tying the employees to company via stock ownership is not accomplished. However, this function is rarely accomplished even with regular options. The reason for this is the taxation, which forces the option holder to reassign or sell the options rather than subscribe the underlying shares.

2.5 Tax reasons

To attract employees to deferred compensation instead of regular wage the deferred compensation has to be preferable. According to Scholes (1991) the corporation would be indifferent to paying 1€ of current salary or deferred compensation in the amount of DC_n where

$$DC_n = \frac{(1-t_{co})(1+r_{cn})^n}{(1-t_{cn})} \quad (3)$$

t_{co} is the current corporate tax rate, t_{cn} is the future corporate tax rate and r_{cn} is the after-tax corporate rate of return on the invested funds. For preferred compensation to be preferred to current salary for tax reasons, it is necessary that

$$\frac{(1-t_{co})(1+r_{cn})^n(1-t_{pn})}{(1-t_{cn})(1+r_{pn})^n(1-t_{po})} > 1 \quad (4)$$

where t_{pn} is employee's tax rate in the future, t_{po} is employee's current tax rate and r_{pn} the after-tax rate of return on investment for the employee. This equation (4) becomes evident when looked closer. If the result of this equation becomes smaller than 1, it is more profitable for the employee to take the salary instead of deferred compensation. However, tax rules encourage deferred compensation programs when corporate after-tax returns exceed personal after-tax return, and even more so if corporate tax rates are expected to fall relatively less than employee tax rates (Scholes, 1991).

3 Stock options and incentives

Because of agency problems (Jensen and Mecling, 1976), corporate governance and incentive problems are enormous in large publicly traded companies. It is very difficult to align the incentives of managers with the goals of owners. Ownership of such companies is quite diffuse and the large size of the companies makes it difficult for CEOs to purchase a large proportion of the firm's equity. As a result, managers often take actions and make decisions that are at odds with shareholder value maximization. The issue of optimal compensation package is largely debated in financial press. The most direct way to reduce agency problems is through high-powered incentive schemes; that is, by tying CEO pay very closely to shareholder value creation. In very large corporations this is difficult to do, because typical swings in the market value of large corporations are quite large relative to the wealth of CEO. For example, imagine a company with a market value of 10 billion €. A 30% change in the market value (which is approximately equal to the annual standard deviation of returns of the largest companies) represents a 3 billion € change in the shareholder wealth. If CEO wealth changed by even 10% of that value, CEO wealth would increase or decline by 300 million €. Very few CEOs have enough wealth to make this type of contract even remotely feasible. Moreover, even if contracts with such large swings in CEO wealth could be written, it is not clear that such contracts would be optimal given CEO risk aversion[5] (Hall, 1999-Jennifer Carpenters book). Hall and Liebman (1998) have estimated that the elasticity of CEO compensation has been 0,24 for the late 1980s and early 1990s. What this means is that an increase of 10% in company value increases CEO's salary by 2,4%. For the same change in company value, revaluations of CEO stock and stock options are much larger. In reality however it is very difficult to bind CEOs' wealth to swings in company

[5] If incentives are too high-povered, the resulting large swings in CEO wealth may lead CEOs to avoid high-risk, high-return projhects that are desirable from the perspective of diversified shareholders. That is, CEOs may price idiosyncratic risk (Hall and Liebman, 1998).

value. This is simply because companies are so large. In their article Jensen and Murphy used data from the 1970s and early 1980s and showed that total CEO wealth changed by only $3,25 cents for every $1000 change in shareholder value, concluding CEOs are essentially paid like bureaucrats.

The incentives provided by options are not well understood, either by the boards which grant the options or the employees who receive options. In order to understand the incentives provided by the options it is essential to understand the value of options to their holders. Valuing options is not so intuitive. Two economists, Robert Merton and Myron Scholes, were recently awarded the Nobel Prize for developing the framework for valuing options. The ones not acquainted with share options might claim that options are not effective compensation tools since stock options have only upside potential and not downside risk. In a recent paper Hall (1998) analyzed the pay to performance incentives created by executive stock options, which are summarized here.

There is indeed downside risk to stock options. If the proper thought experiment is conducted, then it is the case that stock options have more downside risk than stock. Explanation at this point is necessary. The view that stock options have limited downside risk rests, at least in part, on the fact that, when the stock prize changes the value of option changes less than the prize of a share. That is, an options delta is less than one, and falls as the stock prize pushes an option contract further out of the money. While this is correct, it does not imply that options have little downside risk. Options have value. As the price of the stock falls, the value of option also falls. The only question is by how much? Hall has conducted an example that clarifies this matter well.

	Stock	Out of the money options	At the money options
# of shares/options (in millions)	1	4.17	3.06
Times delta (change in the value of one share or one option per $1 change in stock price)	1	0.45	0.55
Equals sensitivity (in millions)	1	1.88	1.67
Example 1: Increase in share price from $1 to $1.25			
# of shares/options (in millions)	1	4.17	3,06
Times delta	1	0.48	0.57
Equals sensitivity (in millions)	1	2	1.73
Times price change	$0.25	$0.25	$0.25
Equals total change in value	$0.25 million	$0.5 million	$0.43 million
Example 1: decrease in share price from $1 to $0.75			
# of shares/options (in millions)	1	4.17	3.06
Times delta	1	0.41	0.51
Equals sensitivity (in millions)	1	1.71	1.56
Times price change	($0.25) million	($0.25) million	($0.25) million
Equals total change in value	($0.25) million	($0.43) million	($0.39) million

Table 3.1. Option's sensitivity to share price movements.

Hall used material from the typical CEO stock option grants of the Fortune 500 companies. He found that typical stock option was at the money and had duration of 10 years. The typical Fortune 500 Company had dividend rate of about 3.5% and stock prices with annual standard deviations of about 32%. Under those assumptions, an "at the money" option has delta of about 0.55-that is, the value of one option change by 55% of the value of one share of stock. The key, however, is this: for the same ex ante value transfer to the CEO, a company can give a greater number of stock options than shares because each option is worth less than each share. In fact, a company can give about three times as many options as shares for the same ex ante value transfer to the CEO. More importantly, the greater sensitivity induced by a larger number of shares more than offsets the lower sensitivity per option (relative to stock). As shown on the table x.x, for the typical stock option, a company can transfer about three at the money options for every transfer of one share. Since each option has a delta that is about 0.55, the total sensitivity of option is about 1.7 (3 times 0.55) times higher than that of stock. This is the leverage effect of stock options as a compensation tool.

The fact that out of the money options have smaller delta than those at the money does not imply that these options are less affected by downward movements of share price. An option with an exercise price that is 50% above the stock price is worth only about one-fourth of one share of stock, which means that company can give about four options for every share (see table 3.1). Since each out of the money option has a delta of about 0.45, the total sensitivity is 1.88 times larger than that of stock. Out of the money options have even greater sensitivity than at the money options. This includes downside as well as upside sensitivity.

The table 3.1 illustrates the leverage effect of options. The benchmark transfer to the CEO is \$1 million worth of stock. The CEO is granted 1 million shares of stock each worth \$1. If the stock price increases by 25%, from \$1 to \$1.25, the CEO realizes gain of \$0.25 million. If the CEO is given \$1 million worth of at the money stock options instead the same rise in share price will cause gain of \$0.43 million rather than \$0.25 million. This is caused by the fact that CEO is granted 3 times as many options as shares and thus the sensitivity is larger.

When the CEO is holding out of the money options the gain is even higher as shown in the table 3.1. As seen on the table 3.1 the same basic logic applies to downward movements as well. However, the leverage effect of options is slightly smaller since the option deltas fall as the stock price falls.

4 Valuation

The formulas and conclusions disclosed in this chapter can be found on the article written by Lisa K. Meulbroek in the Financial Management journal summer 2001.

4.1 Equity-linked compensation

The total cost imposed on the manager by his compelled holding of equity-based compensation has two components. The first is the cost associated solely with the loss in diversification. The second is the cost arising from the specific pattern of risk exposure created by the financial instrument the manager is required to hold. Financial engineering can reduce or eliminate the second component of cost, but the first component, the cost due to the loss of diversification, cannot be eliminated without destroying incentive alignment.

To estimate this loss of diversification cost I calculate the expected return expected a manager would require in order to be indifferent between holding a portfolio consisting only of the firm's stock, and holding an efficiently diversified portfolio levered to a volatility level that equals that of the firm's stock. Sharpe ratio approach is used to lever the volatility level of the portfolio consisting only firm's stock to the portfolio that is efficiently diversified. The beginning assumption is that CAPM holds instantaneously in a continuous-time model, an assumption consistent with the underlying assumptions of the Black-Scholes option-pricing model, which is used later to value executive options. This assumption produces mean-variance behaviour. Mean-variance behaviour implies that even people with high-risk tolerances, such as entrepreneurs, prefer the higher expected return produced by a leveraged fully diversified portfolio to the lower expected return from an equally risky single-stock portfolio. In the Black-Scholes model, and in continuous-time portfolio theory, the security market line relation is expressed in instantaneous expected-rates-of-return:

$$r_j = r_f + \beta_j (r_m - r_f) \quad (5)$$

Where $e^{r_f} \equiv (1 + R_f)$ where R_f represents the riskless arithmetic return, and r_f is, therefore, its continuously-compounded equivalent.

$e^{r_j} \equiv$ (1 + yearly expected rate-of-return of security *j* under CAPM pricing)

$e^{r^u_j} \equiv$ (1 + yearly expected rate of return on security *j* required by an undiversified mean-variance optimising investor to make that investor indifferent between holding stock *j*, and holding a market portfolio with volatility equal to that of stock *j*)

$(r_m - r_f)$ = The market's risk premium (continuously-compounded)

r_m = The expected market return (continuously-compounded)

σ_m = The market's volatility

β_j = Firm *j*'s beta from CAPM

σ_j = Firm *j*'s volatility

Define $s_j \equiv r^u{}_j - r_j$, as the instantaneous spread between the expected return required by an undiversified investor relative to the CAPM-based expected return. This spread represents the compensation an undiversified investor must receive in order to be indifferent between holding only stock j in his portfolio, and holding the market portfolio.

4.1.1 Sharpe ratio

Calculating average portfolio return does not mean that task is done. Returns must be adjusted for risk before they can be compared meaningfully. The simplest and most popular way to adjust returns for portfolio risk is to compare rates of return with those of other investment funds with similar risk characteristics. However, this comparison of performance with other funds can be misleading. For example, within a particular universe, some portfolios may consist particular subgroups, so that portfolio characteristics are not truly comparable. With this in mind a more precise means for risk adjustment is desirable. Methods of risk-adjusted performance evaluation using mean-variance criteria came on stage simultaneously with the capital asset pricing model (CAPM). Jack Treynor, William Sharpe and Michael Jensen recognized immediately the implications of the CAPM for rating the performance of portfolios. This performance ratio is called the Sharpe ratio and is presented as follows:

$$\mathrm{S} = \frac{E(r_p) - r_f}{\sigma_p} \quad \text{, where} \quad (6)$$

r_p is expected portfolio return, r_f is risk free return and σ_p is volatility of the portfolio.

Using Sharpe ratio required return expected by an undiversified investor (r_j^u) can be solved as follows:

$$\frac{r_m - r_f}{\sigma_m} = \frac{r_j^u - r_f}{\sigma_j} \Rightarrow r_j^u = r_f + \left[\frac{\sigma_j}{\sigma_m}\right](r_m - r_f) \quad (7)$$

Knowing r_j^u and r_j yields s_j $(s_j \equiv r_j^u - r_j)$, and

$$s_j = \left(\left[\frac{\sigma_j}{\sigma_m}\right] - \beta_j\right)(r_m - r_f) = \left[\frac{\sigma_j}{\sigma_m}\right](1 - \rho_{jm})(r_m - r_f) \quad (8)$$

Where ρ_{jm} is the correlation coefficient between firm j's returns and market returns.

4.1.2 Calculating the value of stock to employee

Let $V_j(t)$ = Value of stock *j* at time t (the market price).

T = Date at which the undiversified investor is free to sell the stock.

For analytical simplicity it is assumed that firm pays no dividends during $t \leq T$, the duration of sale restriction. The discounted future value of the firm j at the time T equals today's stock price:

$$V_j(t) = e^{-r_j T} E_t\{ V_j(T)\} \quad (9)$$

, where $E_t\{\bullet\}$ is the conditional expectation of the value of the shares of *j* at T, conditional on the information available at time t. Similarly, by definition of r_j^u , we know that the expected future value of the firm to the undiversified investor discounted by r_j^u is the value of the firm today to the undiversified investor.

$$V_j^u(t) = e^{-r^u_j T} E_t\{ V_{j^u}(T)\} \quad (10)$$

But, at date T, the undiversified investor is free to sell his shares in the open market, so therefore, at date T for every outcome, the value of the stock to the undiversified investor, $V_j^u(t)$, will equal the market value of the firm:

$$V_j^u(T) = V_j(T) \quad (11)$$

Hence, this statement must hold expectationally as well:

$$E_t\{ V_j^u(T)\} = E_t\{ V_j(T)\} \quad (12)$$

By substituting equation 11 into equations 9 and 10, we have:

$$V_j^u(t) = e^{-r^u_j T} E_t\{V_j(T)\} = e^{-r^u_j T} \times e^{-r_j T} \times V_j(t) = e^{-s_j T} V_j(t) \quad (13)$$

The manager's private value of the stock today is its market value today, discounted by the incremental amount required to compensate the manager for the firm's total risk.

$$\text{Efficiency of stock compensation} = \frac{V_{j^u}(t)}{V_j(t)} = e^{-s_j T} \quad (14)$$

As equation (14) shows the efficiency of stock compensation is the ratio of the stock's value to an undiversified employee relative to the cost of that compensation to the firm. The equation also suggests that the longer the employee is required to hold the stock the less valuable the stock is to him. Also, more the company stock's performance correlates with the market's overall performance, higher the efficiency ratio. This is because the higher the correlation the closer the stock's expected return gets to the market's expected return, which lowers s_j, the undiversified investor's required expected return premium.

4.2 Option-based compensation

The basic idea in measuring the efficiency of option-based compensation is same as with equity compensation. However, options are more complicate to value than equity. This is because both the expected return and the standard deviation of the option change at every point in time. As in discussion of stock discount the same framework applies to options, it is assumed that an investor is indifferent between efficiently diversified and concentrated portfolio if the Sharpe's ratio is same for both portfolios. Since employee is required to hold on to the options for certain time period, he values the options less than efficiently diversified investor.

Option value consists of two parameters. *First* is *the intrinsic value* of option. This is simply calculated by subtracting the option's exercise price from the current market price. If the market value is less than exercise price, the intrinsic value of option is zero. Of course the value of option cannot be less than zero ant thus although the exercise price exceeds the market price the option holder is not liable to pay out the difference. The *second* parameter of option value is the *time value*. Option's time value increases the longer the time to option expiry. Because of the time value the option value can be greater than zero even though the intrinsic value of option is zero. Valuing time value of the option is not as straight forward as calculating its intrinsic value and thus various option valuation methods for valuing options are developed. Most commonly used methods are binomial model and Black-Scholes model. The method used in this thesis context is the Black-Scholes model. Black-Scholes model is widely used by practioners for its ease of use.

4.2.1 The Black-Scholes formulae

The Black-Scholes formula is derived by Fisher Black, Myron Scholes and Robert C. Merton. Scholes and Merton shared the 1997 Nobel Prize in economics for their accomplishment. Black-Scholes formula can be described as follows:

$$C_0 = S_0 N(d_1) - Xe^{-rT} N(d_2) \quad (15)$$

where

$$d_1 = \frac{\ln(S_0 / X) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}} \quad (16)$$

$$d_2 = d_1 - \sigma\sqrt{T} \qquad (17)$$

and where

$C_0 =$ Current call option value.

$S_0 =$ Current stock price.

N(d) = The probability that a random draw from a standard normal distribution will be less than *d*. This equals the area under normal curve up to *d*.

X = Exercise price.

e = 2,71828, the base of the natural log function.

r = Risk-free interest rate (annually continuously compounded).

T = Time to maturity of option, in years.

ln = Natural logarithm function.

$\sigma =$ Standard deviation of the annualized continuously compounded rate of return of the stock.

The option value does not depend on the expected value of the stock. This information is already built into the formula with the inclusion of the stock price, which itself depends on the stock's risk and return characteristics. This version of the Black-Scholes formula assumes that the firm does not pay dividends.

There are, however, some limitations in this formula. *First* is that the model expects that the risk free interest rate stays constant over time. *Secondly*, stock volatility is assumed to be constant over time. When calculating the values of traded options these assumptions would be mitigated by the fact that traded options' time till expiration is usually much shorter than employment options' expiration date. For shorter periods of time both the risk-free rate and volatility may well stay constant but for longer periods this assumption does not hold. *Third* limitation is that the Black-Scholes model assumes a European option that can not be exercised before maturity. This causes a problem since typical employment option is American, which means that the option holder can exercise the option right before maturity. However, this is mitigated by the fact Merton represented in 1973. He demonstrated that it is irrational to exercise a publicly traded American option before the maturity date if the underlying stock is non-dividend paying. *Fourth* limitation concerns transferability. It is a common practice that the person to whom options have been granted loses his right to exercise them if he leaves the company. This reduces the value of option compared to traded "normal" options.

4.2.2 Calculating the value of option to employee

Merton (1990) showed that instantaneous expected return on the employee's option is given by:

$$r_{jo} = \frac{\left[\frac{1}{2}\sigma_j^{\,2} V_j^{\,2} f_{vv} + r_j V_j f_v - f_T\right]}{f} \quad (18)$$

Where f (V, r) is the Black-Scholes value of the option and subscripts on f denote partial derivatives with respect to the share price V and time until expiration, T. Similarly, from Merton (1992), we have the instantaneous standard deviation of the return on the option, σ_{jo}, which can be written as:

$$\sigma_{jo} = \frac{\sigma_j V_j f_V}{f} \quad (19)$$

From equation 19 follows that the instantaneous expected excess return, $r_{jo} - r_f$, can be expressed as:

$$r_{jo} - r_f = \frac{\left[\frac{1}{2}\sigma_j^{\,2} V_j^{\,2} f_{VV} + r_j V_j f_V - f_T - r_f f\right]}{f} \quad (20)$$

By taking the ratio of equation 20 to equation 19, we then have the instantaneous Sharpe ratio of the option return given by:

$$\frac{r_{jo}-r_f}{\sigma_{jo}}=\frac{\left[\frac{1}{2}\sigma_j{}^2V_j{}^2f_{VV}+r_jV_jf_V-f_T-r_ff\right]}{\sigma_jV_jf_V} \quad (21)$$

Following the stock efficiency derivation we now require that the option be priced so that at every point in time it has a Sharpe ratio equal to the Sharpe ratio of the market portfolio. From equation 21 we have:

$$\sigma_jV_jf_V\left(\frac{r_m-r_f}{\sigma_m}\right)=\frac{1}{2}\sigma_j{}^2V^2{}_jf_{VV}+r_jV_jf_V-f_T-r_ff \quad (22)$$

By rearranging terms, *f* must satisfy the partial differential equation:

$$0=\frac{1}{2}\sigma_j{}^2V_j{}^2f_{VV}+\left[r_j-\frac{\sigma_j}{\sigma_m}(r_m-r_f)\right]V_jf_V-r_ff-f_T \quad (23)$$

$\beta_j=\rho_{jm}(\sigma_j/\sigma_m)$ and substituting for r_j from equation 5 into equation 23:

$$0=\frac{1}{2}\sigma_j{}^2V^2{}_jf_{VV}+\left[r_f-(1-\rho_{jm})\frac{\sigma_j}{\sigma_m}(r_m-r_f)\right]V_jf_V-r_ff-f_T \quad (24)$$

where $s_j\equiv r^u{}_j-r_j$, the return premium that an undiversified investor in the stock would require to make her indifferent between holding the stock and holding the market portfolio levered to the volatility level of the stock. From equation 24 and the definition of s_j:

$$0=\frac{1}{2}\sigma_j{}^2V^2{}_jf_{VV}+\left[r_f-s_j\right]V_jf_V-r_ff-f_T \quad (25)$$

This equation is the partial differential equation for the Black-Scholes option-pricing formula on a stock which pays a proportional dividend at rate s_j (Merton, 1992). The well-known solution to this partial differential equation is the Black-Scholes formula for a proportional dividend on stock:

$$f = V_j e^{-s_j T} N(d_j) - Xe^{-r_f T} N(d_j - \sigma_j \sqrt{T}) \quad (26)$$

Where:

$$d_j = \frac{\ln(V_j / X) + (r_f - s_j + \frac{1}{2}\sigma^2{}_j)T}{\sigma_j \sqrt{T}}$$

By substituting equation 13,

$$V_j^u(t) = e^{-r^u{}_j T} E_t\{V_j(T)\} = e^{-r^u{}_j T} \times e^{-r_j T} \times V_j(t) = e^{-s_j T} V_j(t)$$

into equation 26, it follows that:

$$f = V_j^u N(d_j) - Xe^{-r_f T} N(d_j - \sigma_j \sqrt{T}) \qquad (27)$$

Where $d_j = \dfrac{\ln(V_j^u / X) + \left(r_f + \frac{1}{2}\sigma_j^2\right)T}{\sigma_j \sqrt{T}}$

Equation 27 is the Black-Scholes formula with V_j^u as the stock price. Therefore, the pricing on an option that, at every point in time provides an instantaneous Sharpe-ratio equal to the instantaneous Sharpe ratio on the market portfolio, is exactly the Black-Scholes formula on a non-dividend paying stock where we replace the market price of the stock V_j by its discounted private value, $V_j{}^u$, as follows:

$$\text{Efficiency of option compensation} = \frac{f(V_j{}^u, T-t, \sigma_j, r_f, X = V_j)}{f(V_j, T-t, \sigma_j, r_f, X = V_j)} \qquad (28)$$

Where the exercise price (X) is V_j, the amount a employee would actually have to pay to exercise the option, and the denominator is the market value of the option.

5 Volatility

Volatility affects option price significantly and therefore it is important to define future volatility as accurately as possible. The well-known fact is that larger volatility means greater option price. The reason for this is that with large volatility the possibility that the underlying share price is very high or very low is greater. When call-options are concerned the low share price is not a problem since the holder of a call option is not obliged to use the option. However, very high share price increases the value of the option. Reverse is true when put options are concerned i.e. low share price contributes to high put option value. There are two general approaches for estimating the volatility, historical volatilities and implied volatilities.

5.1 Historical volatility

The Black-Scholes formula is straightforward to use and thus it is widely used among practioners. All the inputs needed for the formula except volatility are easy to find and objective. However, the volatility is not so simple to define. Usually historical volatilities of the underlying stock are used. The problem with historical volatilities is that they describe the past and not the future. Historical volatilities are also dependent of the time period used. There might be one year within the volatility has been large due to overall economic situation. If this volatility is then used to value option today it is clear that the outcome is wrong. The sample size is paradox, the larger number observations more accurate the estimate becomes but if the sample size becomes too large one certainly loses some information of the current price movements. Observations recorded long time ago may contain very little information about the current price.

Extensive research in this field has resulted in proposal and development of a variety of models and procedures which are either motivated by the notion that (1) option prices contain valuable information about the future volatility of the underlying asset or that (2) historical financial market volatility calculated from fitting an appropriate volatility model can be successfully cast into the future (Hol, 2003). Models widely used nowadays are Stochastic Volatility (SV) and Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models.

5.2 Implied volatility

Opposed to historical volatilities that are considered as given factors to Black-Scholes model the implied volatility method gives different approach to the subject. The assumption behind this method has to be that model gives correct option values and that the volatility is constant over time. According to geometric Brownian motion implied volatility should be constant to all options with the same underlying asset. If it is not, it would mean that the underlying asset does not follow the geometric Brownian motion or that the markets are not working efficiently. However, next chapter shows that in reality the implied volatilities are not constant. Calculating the implied volatility works backwards, meaning that the option value from the market is taken as fixed and using Black-Scholes formula the implied volatility is derived. The Black-Scholes formula cannot be inverted by traditional calculus to solve the implied volatility. The only way to determine the implied volatility is to use an iterative technique using e.g. MS Excel. Where historical volatility is a retrospective volatility measure and, provided that the historical data is available, can be calculated for any variable whereas implied volatility is only available for those financial assets on which options are traded.

There are several ways to use implied volatility to forecast future volatilities. The following can be found from Hol (2003).

The information value of implied volatility has been established in numerous empirical studies. The hypothesis tested is that the information content of implied volatility should subsume that of all other variables in the information set, provided that the market is efficient and that the correct option model has been applied to infer the implied volatility measure. In that case implied volatility forecasts should be more accurate than historical volatility forecasts.

Since option series do not result in unique values for implied volatility the question arises which option series should be selected in order to obtain the market's volatility forecast with regard to the underlying asset[6]. Following initial research by Latané and Rendleman (1976) implied volatility is often inferred from a number of options and a weighting scheme is applied. The simplest approach is to weight all implied volatilities equally as in, for example, Schmalensee and Trippi (1978). Above it was shown however that certain options result in more accurate implied volatility measures than others and it therefore appears reasonable to give more weight to such options. Schmalensee and Trippi (1978) circumvented this problem by simply excluding those options that were far into or out-of-the-money and options which were close to maturity. Latané and Rendleman (1976) related their weights to the option's vega where the options that exhibited a higher degree of sensitivity to the implied volatility measure were weighted more heavily, thus emphasising implied volatility inferred at-the-money options. They examined 24 individual stocks using weekly observations from October 1973 to June 1974.

The unique feature in Finnish markets is that employment options can be listed in the Helsinki Stock Exchange. This makes it possible to compare the difference between theoretical Black-Scholes value of the option and the current market value of the option. If we agree that all the other parameters except the volatility in the Black-Scholes formula are fixed we can calculate implied volatility of the option. The implied volatility can be seen as market's prediction of the future volatility of the underlying stock. Investors can then judge whether the actual (historical) volatility exceeds the implied volatility. If it does, the option is considered a good buy; if actual volatility seems greater than the implied

[6] The rationale behind using more than one option series is that the noise present in implied volatilities is diversified.

volatility, its fair price would exceed the observed price. It can be that market participants see the risk differently and thus the market price differs from the theoretical value.

6 Data

6.1 Sources

Data for this study were obtained from various sources. Share price time series were taken from Helsinki School of Economics' (HSEBA) database from years 1997 to 2002. The share price time series are daily logarithmic returns of the shares in the Helsinki stock exchange. Historical volatilities were calculated using this data on yearly basis. The results were annualised assuming 250 trading days a year. The formula for the annualised stock return volatility is

$$\sigma_{annual} = \sigma_{daily} \times \sqrt{250} \qquad (29)$$

The market prices of options and shares were attained from the Helsinki stock exchange's Internet service between dates 10.11. -12.11.2003.
The companies were chosen according to their turnover i.e. 20 largest companies were taken into this study. These companies are Elisa, Elqoteq, Finnair, Fortum, Huhtamäki, Kemira, Kesko, Kone, Metso, Nokia, Orion, Outokumpu, Rautaruukki, SanomaWSOY, StoraEnso, Tamro, Sonera, UPM, Wärtsilä and YIT (alphabetical order). However, Kemira, Kone, Rautaruukki, StoraEnso and Wärtsilä were excluded on account that those companies' employment stock options were not listed. The remaining 15 companies' options are listed and thus they qualified to this study.

6.2 Volatilities

Historical volatilities were calculated for sample companies from year 1997 to 2002.

Year	Elisa	Elcoteq	Finnair	Fortum	Huhtamäki	Kesko	Metso	Nokia A	Orion-yhtymä A
1997	-	-	0,271	-	0,276	0,224	-	0,412	0,240
1998	-	0,525	0,373	-	0,470	0,299	-	0,502	0,325
1999	0,429	0,486	0,318	0,208	0,405	0,339	0,275	0,479	0,324
2000	0,645	0,695	0,315	0,239	0,376	0,348	0,384	0,559	0,324
2001	0,660	0,835	0,314	0,262	0,349	0,331	0,386	0,612	0,324
2002	0,625	0,798	0,303	0,272	0,336	0,315	0,378	0,614	0,324
Average	**0,590**	**0,668**	**0,316**	**0,245**	**0,369**	**0,309**	**0,356**	**0,530**	**0,310**

Year	Orion-yhtymä B	Outokumpu	San WSOYA	San WSOYB	Sonera	Tamro	UPM	YIT
1997	0,238	0,313	-	-	-	0,229	0,338	0,263
1998	0,322	0,434	-	-	-	0,438	0,398	0,375
1999	0,322	0,433	0,562	0,390	0,408	0,438	0,396	0,372
2000	0,322	0,434	0,594	0,418	0,615	0,439	0,397	0,372
2001	0,322	0,435	0,636	0,414	0,694	0,440	0,397	0,373
2002	0,323	0,435	0,625	0,393	0,667	0,441	0,396	0,374
Average	**0,308**	**0,414**	**0,604**	**0,404**	**0,596**	**0,404**	**0,387**	**0,355**

Table 6.1. Historical yearly volatilities for each company. Calculated from daily lognormal returns and annualised assuming 250 trading days/year. Equally weighted average was calculated including all years from 1997 to 2002, if available.

In table 6.1 I have calculated the yearly volatilities for the companies based on historical data attained from the daily returns from Helsinki stock exchange. For some companies it was not possible to calculate historical volatilities for all the years since the company was not listed at the time or the share series has changed due for example merger. The arithmetic mean was calculated for each company weighting each year equally. These means are used as an input to Black-Scholes formula.

In comparison I have also calculated implied volatilities for the target companies. Implied volatilities for the companies are calculated based on call option listings on Hex and Eurex. Some call options listed on the Eurex or Hex are not traded every day and thus there is no valid price for such option. For this "vagueness" of the market it is not easy to calculate implied volatilities for companies whose options are less or not at all traded in the Eurex or Hex.

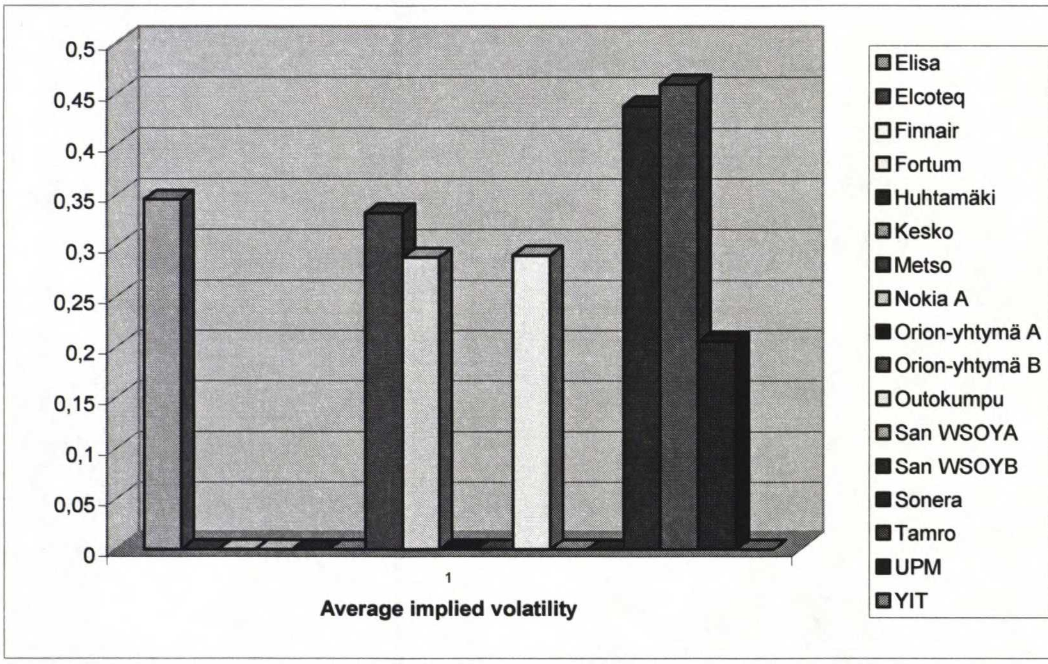

Chart 6.2. Average implied volatility for each company. In calculating means each option series for each company was weighted equally.

As can be seen from the chart 6.2 it was not possible to calculate average implied volatilities for all the companies. This is simply because there was no trading on those companies' options and thus no price quote on the particular option or that the option matures shortly and thus there is no time value left (only intrinsic value to which volatility does not affect). For seven companies, however, it was possible to calculate implied volatilities. These companies are Elisa, Metso, Nokia, Outokumpu, Sonera, Tamro and UPM. In calculating implied volatility I used information gathered from the Eurex and Hex lists.

Eurex is the world's leading futures and options market for euro denominated derivative instruments. Its electronic trading platform provides access to a broad range of international benchmark products. With market participants connected from 700 locations worldwide, trading volume at Eurex exceeded 801 million contracts in 2002, surpassing the previous year's total by 19 percent. After just 10 months of trading, the derivatives market has already turned over 874 million contracts, surpassing the total volume traded in all of 2002 (801 million contracts) by 73 million contracts well before the end of the current year. (http://www.eurexchange.com/index.html, December 2003)

Nokia's options are the most traded in Finland and similarly there were many Nokia options listed also in Eurex. Also Sonera (Now Telia Sonera) and UPM had more than two options that were traded during investigation. Because of the Nokia weightiness of option trade in Finland the other companies' options are less or not at all traded every day. This makes it impossible to for market makers to determine a price for such an option. Both Hex and Eurex act as a market maker. According to Eurex rules the market maker is defined as follows (http://www.eurexchange.com/download/rules/rules_exchangereg_download_en.pdf, December 2003):

An Exchange Participant may also apply for admission as a Market Maker for one or more products if the Board of Management of the respective Eurex Exchange has decided to conduct market making with respect to the trading of such product or products. Each product as to which an applicant seeks admission as a Market Maker must be specified in the application. A Market Maker Admission entitles the holder to engage, for its own account, in the trading of those products with respect to which such Market Maker has accepted the obligation to supply bid and ask quotes promptly upon request at any time during the Opening Period and the Trading Period and to do business on the basis of such quotes. The Board of Management of the respective Eurex Exchange will grant the applicant a Market Maker Admission if the persons named in the application for such form of trading (Exchange Traders) have the requisite trading knowledge to act as Market Makers. The Market Maker Admission shall list all products to which such admission shall relate. Evidence of the requisite technical knowledge must be furnished by the applicant. The Market Maker Admission shall depend on the effectiveness of the admission as an Exchange Participant. A Market Maker is authorized and, upon receipt of a request for a quote for any options contract with respect to any product included in its admission, obliged promptly to supply bid and ask quotes for such options contract and to enter into transactions in such options contract. A Market Maker must be available at all times during exchange hours. A Market Maker is obliged to enter bid and ask quotes to the extent determined by the Board of Management of Eurex Deutschland or Eurex Zürich.

It was interesting to notice how large the deviations of the implied volatilities among various options of the same company are. Even options with same maturity have large differences.

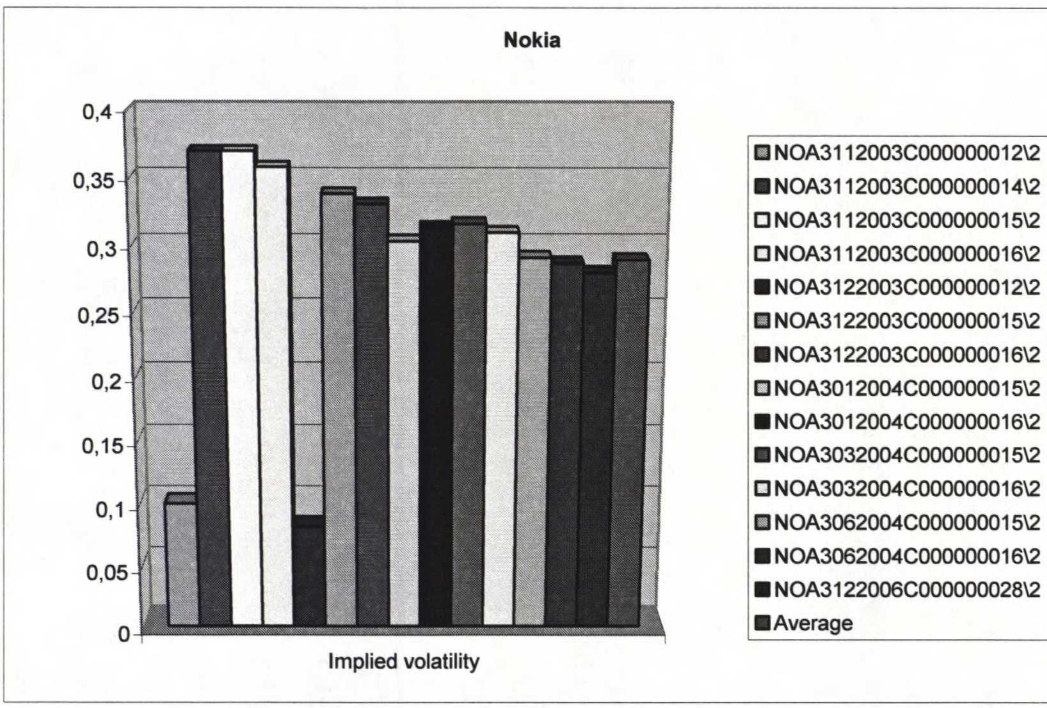

Chart 6.3. Implied volatilities calculated from Nokia options listed at Eurex.

As can be seen from the chart 6.3 starting from the left four first pillars show the implied volatility of Nokia options that mature at the same time. The first pillar implies only under 10% annual volatility where as next three pillars indicate over 35% implied volatility. Another very large deviation can be seen between fifth and sixth pillar. They also describe option with the same maturity and the difference between their implied volatilities is whopping 25%. Even though the differences are smaller among other options shown in the chart 6.3 it does not mean that they are insignificant since few percentages change in volatility accumulates into multiple proportional change in the option price.

There are some possible reasons for these large deviations among different option series. Firstly the first and fifth pillars represent options that both mature within 10 or 40 days and they both are well in-the –money (strike: 12, stock price 10.11.2003: 14,95). As Latané and Rendleman (1976) studied some options give more accurate implied volatility measures than others and Schmalensee and Trippi (1978) excluded options that were far in or out-of –the-money or close to maturity, these options should be excluded from the sample. Following these two principles the options, which gave large deviation in volatility compared to other options of the same company, were excluded from the sample. However, out of seven companies only Nokia, Sonera and UPM had sufficient amount (more than two) of options listed in the Eurex at the time to make above described deletion possible. Elisa, Metso, Outokumpu and Tamro had only two or fewer options listed at Eurex that were quoted. For these companies that had only one option which had quote it was not possible to calculate average implied volatility using Eurex listed options. For Metso and Tamro the average implied volatility was calculated from employment options listed at Hex.

These differences imply that there is no objective definition on the market on what the share price after certain period should be. It also makes predicting future volatilities very difficult task.

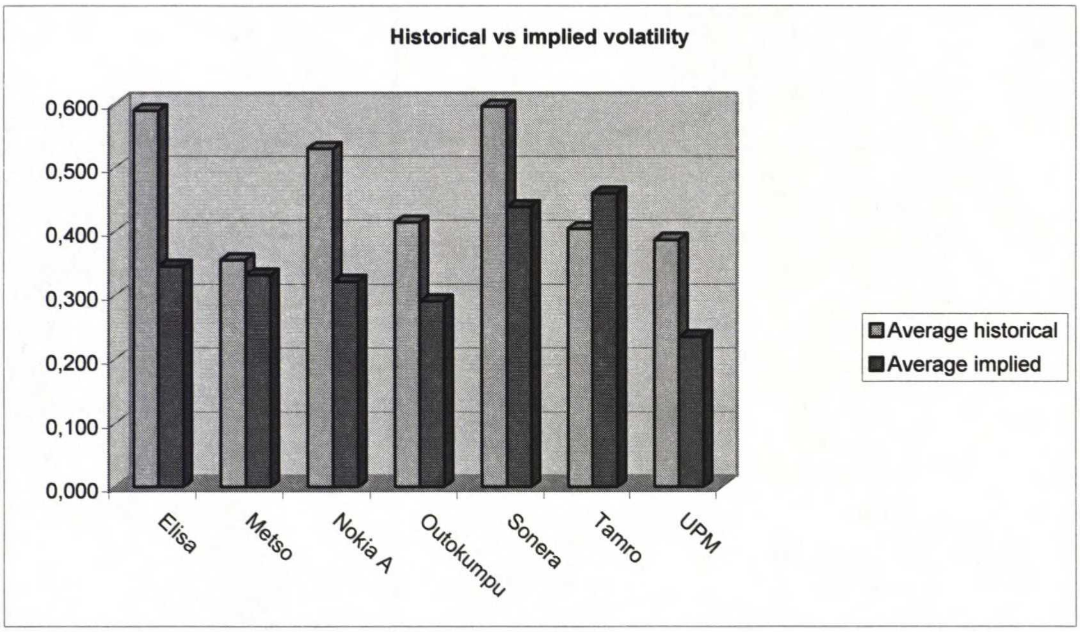

Chart 6.4

As can be seen from the chart 6.4 typically the implied volatilities are below the historical volatilities. The only exemption in this data set was Tamro. Thus when using historical volatilities to value employment option with Black-Scholes model gives larger values than implied volatilities suggest.

The employment options of the target companies that were listed in the Hex per 13.11.2003 are listed below in the table 6.5

Table 6.5. Sample companies' options listed in the Helsinki Stock Exchange.

Company	Option	Market price	Information gathered	Option's mature date
Elisa	ELIAVEW100	0,10	13.11.2003	31.10.2005
Elqoteq	ELQAVEW197	5,10	12.11.2003	31.1.2004
Elqoteq	ELQAVEW101	7,18	12.11.2003	30.4.2007
Finnair	FIA1SEW100	1,15	12.11.2003	31.8.2006
Fortum	FUM1VEW199	4,15	12.11.2003	17.5.2005
Fortum	**FUM1VEW299**	**2,59**	**12.11.2003**	**1.10.2005**
Huhtamäki	**HUH1VEW197**	**0,63**	**13.11.2003**	**31.10.2004**
Huhtamäki	**HUH1VEW297**	**0,63**	**13.11.2003**	**31.10.2004**
Huhtamäki	**HUH1VEW100**	**1,70**	**13.11.2003**	**31.10.2006**
Huhtamäki	**HUH1VEW200**	**2,75**	**13.11.2003**	**31.10.2006**
Kesko	KESBVEW100	2,40	12.11.2003	31.3.2006
Kesko	KESBVEW200	4,00	12.11.2003	31.3.2006
Metso	MEO1VEW100	0,51	12.11.2003	30.4.2005
Metso	MEO1VEW101	0,55	12.11.2003	30.4.2005
Nokia	NOK1VEW199	5,00	10.11.2003	31.12.2004
Nokia	NOK1VEW299	0,01	10.11.2003	31.12.2004
Nokia	NOK1VEW399	0,17	10.11.2003	31.12.2004
Nokia	NOK1VEW101	0,25	10.11.2003	31.12.2006
Nokia	NOK1VEW701	-	10.11.2003	31.12.2007
Nokia	NOK1VEW301	2,29	10.11.2003	31.12.2006
Nokia	NOK1VEW901	-	10.11.2003	31.12.2007
Nokia	NOK1VEW601	0,71	10.11.2003	31.12.2006
Orion	ORIBSEW198	0,62	12.11.2003	30.4.2005
Outokumpu	**OUT1VEW198**	**2,10**	**12.11.2003**	**31.3.2004**
Tamro	TRO1VEW197	0,08	12.11.2003	31.1.2004
Tamro	TRO1VEW100	0,80	12.11.2003	30.4.2006
TeliaSonera	TLS1VEW102	0,13	12.11.2003	30.6.2005
UPM	**UPM1VEW198**	**5,25**	**12.11.2003**	**30.4.2005**
UPM	**UPM1VEW298**	**3,75**	**12.11.2003**	**30.4.2005**
YIT	YTY1VEW198	14,20	12.11.2003	30.11.2003
YIT	YTY1VEW298	14,40	12.11.2003	30.11.2003
Total	31			

The options marked with bold entitle the holder of such option to subscribe more than one underlying share. The market prices of these options are divided by the amount of shares the option entitles the holder to subscribe. Two Nokia options in the table 6.5 have no market price and are thus not included in the study.

6.2.1 Risk free rate

Important input in the Black-Scholes formula besides volatility is risk free rate. Risk free rate is the rate you can earn by leaving money in risk-free assets such as T-bills, money market funds, or the bank. The difficulty of predicting future risk free rates is nowadays harder since risk free rates reflect overall macro economic situation. In this study I have used 12-month Euribor interest rates to predict future risk free interest rates.

European banks considered that the introduction, in 1999, of the single currency made it necessary to establish a new interbank reference rate within the Economic and Monetary Union: Euribor. Euribor (Euro Interbank Offered Rate) is the benchmark rate of the large euro money market that has emerged since 1999. It is sponsored by the European Banking Federation (FBE), which represents the interests of 3,000 banks in the 15 Member States of the European Union and in Iceland, Norway and Switzerland and by the Financial Markets Association (ACI). Euribor is the rate at which euro interbank term deposits are offered by one prime bank to another prime bank and is published at 11.00 a.m. CET for spot value (T+2). Euribor was first published on 30 December 1998 for value 4 January 1999. The choice of banks quoting for Euribor is based on market criteria. These banks are of first class credit standing. They have been selected to ensure that the diversity of the euro money market is adequately reflected, thereby making Euribor an efficient and representative benchmark. A strict Code of Conduct sets out rules covering, amongst other things:

- The criteria used to determine which banks may belong to the panel of banks.
- The obligations of the Panel Banks.
- The tasks and the composition of the Steering Committee, which is responsible for overseeing Euribor.

Moneyline Telerate (formerly Bridge Telerate) has been chosen as the screen service provider responsible for computing and publishing Euribor. Since its launch, Euribor has become a reality on the derivatives markets and is the underlying rate of many derivatives transactions, both OTC and exchange-traded. (http://www.euribor.org/html/content/euribor_about.html, January 2004)

Since on average the options in this study mature within about three years the average of three years Euribor rates were used to estimate future risk free rate. The average 12-month Euribor interest rate during 2000-2002 has been **4,122** per cent (see Appendix 1).

7 Results

7.1 Methods

The market value of employment options were compared to values attained using Black-Scholes option pricing formula. In these calculations two different volatilities were used to get two different option values. These volatilities are historical average volatility and average implied volatility. The historical volatility was calculated for all the target companies in the group using data from the years 1997 to 2002. I calculated an average volatility based on these years and used it to estimate future volatility. Because the historical volatility is calculated with six years of data it mitigates the extreme market conditions experienced between 1999 and 2000 and thus gives more realistic results.

The average implied volatility is gathered from cal options that are listed in Hex/Eurex lists. These options are not employment but regular traded options. The reason for using these options to calculate the implied volatility is that trading activity is larger and thus the results are more reliable than when calculating from the employment options traded solely in the Hex. The problem occurs when there are no options other than employment options listed for one particular company. If that particular company has more than one employment option listed it is possible to calculate average implied volatility based on that information. Nokia, Telia Sonera and UPM had the most market information available from all the 15 companies in this study. For the other 12 companies the market information was scarcer.

I have also analysed the ratio of market option price to the intrinsic value of the option. If under pricing exists it may indicate irrational behaviour since holder of such option may convert the option into shares and sell them into market. Some under pricing may exist since option holders are willing to give some discount to receive the cash without tax risk (Puttonen, Ikäheimo and Kuosa. 2003).

7.2 Historical and Implied volatility

Comparing implied volatilities of employment options to historical share price volatilities it can be concluded that they are well below historical levels. These differences are conducted below in the table 7.1.

Option	Company	Implied vol.	Historical avg.(company shares)
ELQAVEW197	Elcoteq	0,4610	
ELQAVEW101	Elcoteq	0,1963	0,6677
ELIAVEW100	Elisa	0,4418	0,5897
FIA1SEW100	Finnair	0,1892	0,3156
FUM1VEW199	Fortum	0,4379	
FUM1VEW299	**Fortum**	-	0,2453
HUH1VEW197	Huhtamäki	0,1542	
HUH1VEW297	Huhtamäki	0,1542	
HUH1VEW100	**Huhtamäki**	-	
HUH1VEW200	**Huhtamäki**	-	0,3687
KESBVEW100	Kesko	0,0100	
KESBVEW200	**Kesko**	-	0,3095
MEO1VEW100	Metso	0,3379	
MEO1VEW101	Metso	0,3263	0,3557
NOK1VEW199	Nokia	0,2676	
NOK1VEW299	Nokia	0,3806	
NOK1VEW399	Nokia	0,2801	
NOK1VEW101	Nokia	0,2739	
NOK1VEW701	**Nokia**	-	
NOK1VEW301	Nokia	0,3183	
NOK1VEW901	**Nokia**	-	
NOK1VEW601	Nokia	0,2552	0,5299
ORIBSEW198	Orion	0,3135	0,3102
OUT1VEW198	Outokumpu	0,2766	0,4142
TRO1VEW197	Tamro	0,5211	
TRO1VEW100	Tamro	0,3975	0,4041
TLS1VEW102	Teli Sonera	0,2399	0,5961
UPM1VEW198	**UPM**	-	
UPM1VEW298	UPM	0,2743	0,3868
YTY1VEW198	**YIT**	-	
YTY1VEW298	**YIT**	-	0,3547

Table 7.1. Implied volatilities for employment options compared to average Historical volatilities calculated from the daily stock returns.

All the bolded options in the table 7.1 represent options for which implied volatility could not be calculated. There are several reasons for this. Firstly, there might not be market price available for the option (NOK1VEW 701 and NOK1VEW901) and therefore implied volatility could not be calculated. Secondly, the option matures very shortly and thus there is no time value left (the time value depends on volatility). Also, if option matures after long time it might be that reliable volatilities cannot be deferred from the market price. As opposed to formula 28 in page 33 the Finnish markets' special feature, which is the possibility to list employment options, makes it possible to compare theoretical Black-Scholes value to actual market value and get the efficiency of that particular option. Thus there is no need to input different values of shares $\left(V_j^u \, and \, V_j\right)$ since the share price is already discounted in the market value of option. Another thing is that once the employment option is listed there is no lock up period and thus no need to take that into account in calculations. The option is exercisable right away. This eliminates calculating V_j^u (discounted value of company share to the undiversified investor). The influencing factor is the volatility. All the other parameters can be locked. By modifying equation 28 in the page 33 we come up with following equation.

$$\text{Efficiency of option compensation} = \frac{f(V_j, T, \sigma^m{}_j, r_f, X = V_j)}{f(V_j, T, \sigma^{ai\ or\ ah}{}_j, r_f, X = V_j)} \qquad (30)$$

Where σ^m is market volatility of underlying share (denominator is market value of option), σ^{ai} is average volatility calculated from implied volatilities of the target company and σ^{ah} is average volatility calculated from historical volatilities of target company.

As an input for the theoretical Black-Scholes value I have used both average historical volatility from daily return data and average implied volatility data calculated from the implied volatilities. In the following table 7.2 the ratios market to Black-Scholes value are calculated using both average historical volatilities and average implied volatilities. The cells without value mean that it has not been possible to calculate average since there has been only one or less volatilities to count from. There was total of 25 options from which to calculate market to average historical volatility Black-Scholes ratios and 17 to calculate market to average implied volatility Black-Scholes ratios. When using historical average volatilities as an input to Black-Scholes formula it seems that 80 per cent of the options are over priced compared to the market value of the options. When using average implied volatility as an input the proportional amount of over priced options decreases by 9,4 per cent to 70,6 per cent and equally the proportional number of under priced options increase 9,4 per cent to 29,4 per cent. When using average historical volatility as an input we get average over pricing of 45,3 per cent. This drops to 26,2 per cent when average implied volatility is used as input.

Option	Market/B-S (Avg.historical)	Market/B-S (Avg.implied)
NOK1VEW199	0,4287	0,9031
NOK1VEW299	0,0388	76,5725
NOK1VEW399	0,0543	0,8154
NOK1VEW101	0,1110	0,7762
NOK1VEW301	0,5065	1,1460
NOK1VEW601	0,2080	0,7172
TLS1VEW102	0,1694	0,2761
UPM1VEW198	0,8747	1,4827
UPM1VEW298	0,8419	1,0591
MEO1VEW100	0,8736	1,0367
MEO1VEW101	0,8147	0,9520
TRO1VEW197	2,5538	0,1176
TRO1VEW100	0,5358	0,4950
OUT1VEW198	0,9153	0,9908
ELIAVEW100	0,2231	0,9894
ELQAVEW197	0,9762	0,8403
ELQAVEW101	0,7684	0,9868
YTY1VEW198	0,9527	-
YTY1VEW298	1,0122	-
ORIBSEW198	1,0434	-
FIA1SEW100	1,0007	-
HUH1VEW197	0,4532	-
HUH1VEW297	0,4532	-
HUH1VEW100	0,5539	-
HUH1VEW200	0,1689	-
FUM1VEW199	1,0333	-
FUM1VEW299	0,8601	-
KESBVEW100	0,6151	-
KESBVEW200	0,7211	-
Total	25	17
Market < B-S	80,0 %	70,6 %
Market > B-S	20,0 %	29,4 %
Avg.over pricing%	45,3 %	26,2 %

Table 7.2. Market to Black-Scholes ratios for each option. Average implied volatility not available for all companies. Market </> B-S represents comparative amount of options that are below/over B-S value. Average over pricing discloses how much larger value of option on average is derived using Black-Scholes formula compared to market value of option.

7.3 Market vs. intrinsic value

The value of any option is formed from two elements. First is the intrinsic value and second time value. The intrinsic value is the difference between share price and strike price. Intrinsic value is zero or greater (negative value not possible since option holder does not have to pay if the option is in the red). Time value forms another part of option value and is dependent on options time to maturity and on underlying asset's volatility. Greater the time to maturity and volatility also greater the time value of option. If the intrinsic value is greater than market value then in theory it is possible to buy an option and exercise it immediately (employment options are American options-exercisable any time until maturity) and make a profit. In reality there are market inefficiencies and therefore an option holder is willing to e.g. sell the option rather than exercise it because exercising an option means exposing to tax risk. Tax risk occurs when option is exercised and taxable gain is created but the employee may not receive his shares in several days or weeks. If the share price decreases during this waiting period an employee has to pay taxes for a gain he has never actually gained. For this reason some discount in employment options' market prices is acceptable since employees are willing to receive the cash immediately (T+3) without tax risk. In the data set of 29 options there was two options with greater intrinsic value than market value.

Option	Market value	Intrinsic value	Diff.
NOK1VEW199	5,00	0	-5,00
NOK1VEW299	0,01	0	-0,01
NOK1VEW399	0,17	0	-0,17
NOK1VEW101	0,25	0	-0,25
NOK1VEW301	2,29	0	-2,29
NOK1VEW601	0,71	0	-0,71
TLS1VEW102	0,13	0	-0,13
UPM1VEW198	*5,25*	*4,63*	*-0,62*
UPM1VEW298	*3,75*	*2,11*	*-1,64*
MEO1VEW100	0,51	0	-0,51
MEO1VEW101	0,55	0	-0,55
TRO1VEW197	0,08	0	-0,08
TRO1VEW100	*0,80*	*0,49*	*-0,31*
OUT1VEW198	*2,10*	*1,88*	*-0,22*
ELIAVEW100	0,10	0	-0,10
ELQAVEW197	*5,10*	*4,99*	*-0,11*
ELQAVEW101	*7,18*	*5,99*	*-1,19*
YTY1VEW198	***14,20***	***14,88***	***0,68***
YTY1VEW298	*14,40*	*14,20*	*-0,20*
ORIBSEW198	0,62	0	-0,62
FIA1SEW100	*1,15*	*0,49*	*-0,66*
HUH1VEW197	0,63	0,00	-0,63
HUH1VEW297	0,63	0,00	-0,63
HUH1VEW100	*1,70*	*0,82*	*-0,88*
HUH1VEW200	*2,75*	*2,74*	*-0,01*
FUM1VEW199	*4,15*	*3,74*	*-0,41*
FUM1VEW299	*2,59*	*2,49*	*-0,10*
KESBVEW100	*2,40*	*1,30*	*-1,10*
KESBVEW200	***4,00***	***4,06***	***0,06***

Table 7.3. Intrinsic values are calculated by subtracting option's strike price from the current share price at the time. Intrinsic value is allways 0 or more. Thus negative value means that option has intrinsic value of 0. Difference is calculated by subtracting intrinsic value from market value.

In the table 7.3 the column "Diff." is calculated by subtracting market value from the intrinsic value. If the value in the "Diff." column is greater than 0 then the intrinsic value is greater than market value and there is theoretical possibility to make money just by buying an option and immediately exercising it. For YTY1VEW198 and KESBVEB200 the difference is greater than 0. Intrinsic values in the table 7.3 also describe whether the option is in or out of the money. 15 out of 29 options were in the money and are in Italic in the table 7.3.

7.4 Regression analysis

In this chapter factors affecting the appreciation difference between theoretical and market values of employment options are examined. The variables tested are option's market value, option's time to maturity, share price – strike price and in/out-of-the-money variable.

Using regression analysis the variables affecting to the market to Black-Scholes ratio (y) are analysed. The regression formula used is as follows:

$y = b_0 + b_i x_i ...... + b_n x_n$ (31)

The market to Black-Scholes ratios displayed in the table 7.2 in page 49 show clearly how large the difference of these ratios is depending on the volatility we are using. With regression analysis I tried to find out whether options time to maturity, in/out-of-the-money factor and option's market value can be used as defining variables for the ratios. When trying to explain market to Black-Scholes ratios with average historical stock volatilities used as an input the results were as follows:

	Coefficients	*t Stat*	*P-value*
Time to mat.(years)	-0,227	-2,467	0,021
In/out of the money	0,306	1,476	0,153
Market value	-0,014	-0,473	0,640
Adjusted R Square	**0,160**		
Significance F	**0,062**		

Table 7.4. Market to B-S ratio (with average historical volatility) as depending variable. Option's time to maturity, in/out-of-the-money factor and market value as defining variables.

The results disclosed in the table 7.4 indicate that these three factors explain market to Black-Scholes ratios with average historical volatilities accurately (significance F) but the reliability of the results is low (adjusted R square). When the volatility used in the Black-Scholes formula is changed to average implied volatility calculated from the target companies' listed options the results are as follows:

	Coefficients	t Stat	P-value
Time to mat.(years)	-2,502	-0,520	0,612
In/out of the money	-3,901	-0,289	0,777
Market value	-1,050	-0,371	0,717
Adjusted R Square	**-0,149**		
Significance F	**0,819**		

Table 7.5. Market to B-S ratio (with average implied volatility) as depending variable. Option's time to maturity, in/out-of-the-money factor and market value as defining variables.

From the table 7.5 can be seen that there is no statistical meaning in this test. The adjusted R square value decreases below zero, which means that results are not reliable. Also, the F-test indicates that the variables explain this sample set poorly.

By adding one variable that describes how much the option is in or out-of-the-money more accurately increases the adjusted R square value notably compared to the Table 7.4. This variable is share price minus option's strike price. The results are shown below in the Table 7.6.

	Coefficients	t Stat	P-value
Share price-strike	0,006	2,260	0,033
Time to mat.(years)	-0,245	-2,864	0,009
In/out of the money	0,193	0,973	0,340
Market value	-0,027	-0,933	0,360
Adjusted R Square	**0,278**		
Significance F	**0,018**		

Table 7.6. Market to B-S ratio (with average historical volatility) as depending variable. Option's market value, share minus option's strike price, option's time to maturity and in/out-of-the-money factor as defining variables.

Compared to table 7.4 the adjusted R square increases by 0,118 and F-test value decreases. It seems that share minus strike price and time to maturity have lowest P-values and thus their significance is the highest. Both share minus strike price and time to maturity variables are significant at $P<0,05$ level. By excluding option's market value and in/out-of-the-money factors from the analysis increases the adjusted R square value but is still very low in order to make any reliable conclusions.

	Coefficients	*t Stat*	*P-value*
Share price-strike	0,006	2,638	0,014
Time to mat.(years)	-0,208	-2,751	0,011
Adjusted R Square	**0,301**		
Significance F	**0,004**		

Table 7.7. Market to B-S ratio (with average historical volatility) as depending variable.

Respectively, when adding share price minus option's strike price variable to explain market to Black-Scholes ratios using average implied volatilities we get following results:

	Coefficients	*t Stat*	*P-value*
Share price-strike	-0,450	-9,716	0,000
Time to mat.(years)	-0,435	-0,256	0,802
In/out of the money	5,134	1,067	0,307
Market value	0,714	0,710	0,492
Adjusted R Square	**0,860**		
Significance F	**9E-06**		

Table 7.8. Market to B-S ratio (with average implied volatility) as depending variable. Option's market value, share minus option's strike price, option's time to maturity and in/out-of-the-money factor as defining variables.

Compared to table 7.5 the adjusted R square increases significantly and it seems that share price minus strike variable is statistically the most significant factor affecting market to B-S ratio when average implied volatilities are used as an input to the Black-Scholes formula. Also, the F-test implies that these four variables explain this ratio effectively.

8 Conclusions

The Finnish markets offer a unique possibility to compare actual market values of ESO's with theoretical values calculated with Black-Scholes method. However, the theoretical value highly depends on the inputted volatility. It is impossible to determine the correct volatility objectively and thus there is more than one method in estimating the volatility. Two methods used in this study are the historical volatility of the underlying share between 1997 and 2002 and implied average volatility calculated from target company's listed options in the HEX and/or EUREX lists.

The objective of this study was to find out what volatility measures give reliable results when comparing theoretical employment option (ESO) values to the market values, historical or implied volatilities. Theoretical ESO values are calculated using Black-Scholes formula. The effectiveness of the volatility measures is determined using regression analysis with market to Black-Scholes ratio as dependent variable and options time to maturity, option's market value, in/out-of-the-money factor and share minus strike price as explaining variables. The significance of these variables was examined in regard to market to Black-Scholes ratios calculated using average historical and average implied volatilities as an input to Black-Scholes formula.

The main finding of this study is that using historical share volatilities to predict future volatilities causes heavy under pricing compared to market values. 80 percent of the options in this study were over priced compared to market values when historical share volatilities were used. The average over pricing was hefty 45,3 percent. When average implied volatilities were used the percentage of over priced options fell by almost 10 per cent to 70,6 percent but still remained very high. More importantly, the average over pricing fell from 45,3 to 26,2 percent that represents almost 20 percent decrease (see Table 7.2).

By adding the share price minus strike price variable to the regression analysis increases the adjusted R square values irrespective of the volatility measures that are used as an input for the Black-Scholes formula. Share price minus strike price is the statistically significant variable at $p<0,05$ level in all the tests. Based on analysis these four variables explain market to theoretical ratios better when implied average volatilities are used when calculating Black-Scholes values for the ESO's. By adding share price minus option's strike price variable increased the reliability of the tests.

There are some limits that should be taken into account when analyzing the results of the regression analyses. Firstly, implied volatilities were not possible to determine for all the companies since there was no price quote on some companies call options. Secondly, the market prices for the options are based on closing prices between dates 10. –13.12.2003. Were intraday data available, it could have increased the reliability of regression tests.

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Appendices

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Appendix 6

Appendix 1

1.2 Euriborkorot ja eoniakorko

Euriborräntor och eoniaränta - Euribor and Eonia rates

Päiväkeskiarvoja Dagsmedeltal Daily average		Eoniakorko Eoniaränta Eonia rate	Euriborkorot (todell.pv:t / 360) Euriborräntor (faktiskt antal dagar / 360) Euribor rates (actual / 360)														
			1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
			viikkoa - veckor - weeks			kuukautta - månader - months											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1999		2.74	2.817	..	..	2.862	2.913	2.961	3.002	3.033	3.054	3.073	3.093	3.114	3.137	3.160	3.183
2000		4.12	4.177	..	..	4.244	4.325	4.400	4.455	4.509	4.556	4.596	4.639	4.682	4.718	4.753	4.789
2001		4.39	4.371	..	..	4.335	4.297	4.267	4.225	4.191	4.159	4.135	4.116	4.101	4.093	4.088	4.086
2002		3.29	3.304	..	..	3.307	3.315	3.322	3.330	3.341	3.355	3.371	3.391	3.414	3.436	3.466	3.495
2002	I	3.29	3.346	..	..	3.348	3.342	3.339	3.338	3.339	3.342	3.352	3.366	3.388	3.413	3.444	3.483
	II	3.28	3.323	..	..	3.336	3.347	3.357	3.372	3.385	3.398	3.419	3.447	3.479	3.508	3.551	3.594
	III	3.26	3.326	..	..	3.346	3.370	3.391	3.429	3.463	3.500	3.546	3.595	3.649	3.706	3.762	3.816
	IV	3.32	3.315	3.323	3.329	3.336	3.373	3.407	3.445	3.487	3.536	3.584	3.635	3.700	3.749	3.801	3.860
	V	3.31	3.338	3.348	3.355	3.374	3.422	3.467	3.520	3.571	3.626	3.681	3.741	3.800	3.852	3.907	3.963
	VI	3.35	3.359	3.369	3.378	3.384	3.425	3.464	3.503	3.544	3.590	3.645	3.687	3.731	3.777	3.822	3.869
	VII	3.30	3.336	3.342	3.351	3.361	3.388	3.410	3.430	3.453	3.484	3.508	3.531	3.558	3.582	3.612	3.645
	VIII	3.29	3.320	3.324	3.326	3.333	3.342	3.352	3.361	3.374	3.380	3.385	3.393	3.402	3.413	3.427	3.440
	IX	3.32	3.316	3.314	3.315	3.317	3.314	3.310	3.304	3.285	3.270	3.253	3.242	3.233	3.232	3.233	3.236
	X	3.30	3.315	3.314	3.311	3.306	3.275	3.261	3.225	3.193	3.168	3.151	3.134	3.125	3.123	3.123	3.126
	XI	3.30	3.318	3.296	3.267	3.231	3.187	3.124	3.083	3.057	3.037	3.021	3.014	3.010	3.010	3.013	3.017
	XII	3.10	3.006	3.005	2.996	2.979	2.955	2.941	2.920	2.906	2.894	2.883	2.877	2.872	2.872	2.872	2.874
2003	I	2.82	2.854	2.853	2.853	2.855	2.846	2.832	2.808	2.783	2.758	2.746	2.735	2.723	2.715	2.708	2.705
2.1.2003		2.90	2.908	2.905	2.901	2.899	2.880	2.861	2.833	2.811	2.794	2.780	2.765	2.752	2.749	2.740	2.734
3.1.2003		2.89	2.902	2.901	2.898	2.898	2.883	2.863	2.843	2.826	2.814	2.810	2.802	2.798	2.798	2.798	2.797
6.1.2003		2.88	2.892	2.891	2.889	2.886	2.876	2.860	2.835	2.819	2.801	2.796	2.789	2.783	2.781	2.779	2.777
7.1.2003		2.86	2.883	2.883	2.883	2.882	2.871	2.859	2.832	2.813	2.791	2.781	2.772	2.762	2.761	2.756	2.752
8.1.2003		2.84	2.871	2.870	2.869	2.870	2.862	2.853	2.824	2.805	2.777	2.765	2.755	2.749	2.742	2.735	2.731
9.1.2003		2.83	2.854	2.854	2.853	2.854	2.845	2.834	2.799	2.776	2.750	2.741	2.727	2.721	2.713	2.704	2.699
10.1.2003		2.82	2.848	2.849	2.852	2.854	2.847	2.836	2.813	2.789	2.770	2.762	2.752	2.744	2.739	2.732	2.730
13.1.2003		2.82	2.846	2.848	2.852	2.853	2.845	2.829	2.813	2.791	2.767	2.761	2.750	2.739	2.733	2.727	2.722
14.1.2003		2.82	2.844	2.844	2.848	2.853	2.844	2.829	2.812	2.791	2.768	2.760	2.747	2.738	2.731	2.725	2.722
15.1.2003		2.82	2.843	2.844	2.848	2.853	2.845	2.829	2.812	2.789	2.765	2.757	2.748	2.735	2.729	2.725	2.723
16.1.2003		2.82	2.843	2.846	2.847	2.853	2.844	2.828	2.811	2.784	2.761	2.756	2.747	2.734	2.731	2.724	2.722
17.1.2003		2.81	2.844	2.847	2.849	2.854	2.845	2.830	2.812	2.784	2.763	2.754	2.745	2.733	2.726	2.722	2.719
20.1.2003		2.81	2.843	2.849	2.850	2.853	2.845	2.828	2.806	2.780	2.756	2.747	2.736	2.721	2.713	2.707	2.705
21.1.2003		2.81	2.844	2.849	2.851	2.853	2.844	2.831	2.809	2.787	2.760	2.744	2.734	2.722	2.713	2.703	2.702
22.1.2003		2.57	2.827	2.837	2.837	2.842	2.836	2.825	2.803	2.780	2.748	2.730	2.718	2.705	2.696	2.686	2.685
23.1.2003		2.12	2.837	2.836	2.836	2.839	2.835	2.823	2.803	2.777	2.748	2.731	2.719	2.703	2.694	2.685	2.683
24.1.2003		2.81	2.843	2.838	2.837	2.839	2.833	2.819	2.791	2.760	2.732	2.714	2.702	2.688	2.675	2.665	2.660
27.1.2003		2.81	2.845	2.836	2.835	2.835	2.827	2.814	2.784	2.754	2.725	2.707	2.694	2.675	2.663	2.653	2.645
28.1.2003		2.81	2.848	2.837	2.836	2.836	2.826	2.818	2.789	2.760	2.733	2.717	2.703	2.689	2.679	2.670	2.666
29.1.2003		2.80	2.844	2.835	2.835	2.834	2.825	2.813	2.783	2.748	2.720	2.703	2.683	2.667	2.655	2.645	2.638
30.1.2003		2.80	2.836	2.833	2.832	2.833	2.823	2.811	2.784	2.750	2.721	2.706	2.692	2.674	2.665	2.657	2.652
31.1.2003		2.86	2.833	2.832	2.833	2.833	2.823	2.807	2.781	2.745	2.715	2.699	2.681	2.664	2.653	2.644	2.636

Euribor interest rates

Source: Bank of Finland's Internet page 2.1.2004

Appendix 2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,49972618
R Square	0,249726255
Adjusted R Square	0,159693406
Standard Error	0,447650725
Observations	29

ANOVA

	df	SS	MS	F	Significance F
Regression	3	1,667489273	0,555829758	2,773723782	0,062345909
Residual	25	5,009779285	0,200391171		
Total	28	6,677268558			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	0,951816397	0,20288972	4,691299284	8,29332E-05	0,53395749	1,369675304	0,53395749	1,369675304
Time to mat.(years)	-0,227237546	0,092095269	-2,46741825	0,020806997	-0,41691117	-0,037563923	-0,41691117	-0,037563923
In/out of the money	0,306063574	0,207401441	1,475706111	0,152507716	-0,12108739	0,733214538	-0,12108739	0,733214538
Market value	-0,014266521	0,030135187	-0,473417378	0,640023335	-0,076331058	0,047798015	-0,076331058	0,047798015

Market to B-S ratio (with average historical volatility) as depending variable. Option's time to maturity, in/out-of-the-money factor and market valueas defining variables.

Appendix 3

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,257846353
R Square	0,066484742
Adjusted R Square	-0,148941856
Standard Error	19,68890908
Observations	17

ANOVA

	df	SS	MS	F	Significance F
Regression	3	358,9113771	119,6371257	0,308619003	0,818783265
Residual	13	5039,490829	387,6531407		
Total	16	5398,402206			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	13,05830042	10,42137999	1,25302987	0,232264687	-9,455717937	35,57231877	-9,455717937	35,57231877
Time to mat.(years)	-2,501835742	4,815420101	-0,519546725	0,612111646	-12,90491639	7,901244906	-12,90491639	7,901244906
In/out of the money	-3,900958526	13,5071877	-0,288806124	0,777283622	-33,08145784	25,27954079	-33,08145784	25,27954079
Market value	-1,050298364	2,831729858	-0,370903447	0,716683373	-7,167877614	5,067280885	-7,167877614	5,067280885

Market to B-S ratio (with average implied volatility) as depending variable. Option's time to maturity, in/out-of-the-money factor and market value as defining variables.

Appendix 4

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,617592775
R Square	0,381420835
Adjusted R Square	0,278324308
Standard Error	0,414850335
Observations	29

ANOVA

	df	SS	MS	F	Significance F
Regression	4	2,546849351	0,636712338	3,699647746	0,017504431
Residual	24	4,130419207	0,1721008		
Total	28	6,677268558			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	1,129517017	0,203796285	5,542382762	1,06023E-05	0,708902244	1,55013179	0,708902244	1,55013179
Share price-strike	0,006023593	0,002664794	2,260434503	0,033142945	0,000523729	0,011523457	0,000523729	0,011523457
Time to mat.(years)	-0,245492816	0,085728483	-2,863608532	0,008560551	-0,422427673	-0,068557959	-0,422427673	-0,068557959
In/out of the money	0,193139959	0,198590771	0,972552538	0,340476531	-0,216731164	0,603011082	-0,216731164	0,603011082
Market value	-0,026552005	0,028451063	-0,93325177	0,359984765	-0,085272102	0,032168091	-0,085272102	0,032168091

Market to B-S ratio (with average historical volatility) as depending variable. Option's market value, share minus option's strike price, option's time to maturity and in/out-of-the-money factor as defining variables.

Appendix 5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,592058272
R Square	0,350532998
Adjusted R Square	0,300573998
Standard Error	0,408405228
Observations	29

ANOVA

	df	*SS*	*MS*	*F*	Significance F
Regression	2	2,340602965	1,170301482	7,016413392	0,003657987
Residual	26	4,336665593	0,166794831		
Total	28	6,677268558			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	1,090064053	0,151519919	7,194196379	1,21969E-07	0,778610195	1,401517911	0,778610195	1,401517911
Share price-strike	0,006172902	0,002340331	2,637618684	0,01390821	0,001362279	0,010983525	0,001362279	0,010983525
Time to mat.(years)	-0,207700248	0,075505493	-2,750796526	0,010680177	-0,362904113	-0,052496383	-0,362904113	-0,052496383

Market to B-S ratio (with average historical volatility) as depending variable.

Appendix 6

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,945898816
R Square	0,89472457
Adjusted R Square	0,85963276
Standard Error	6,88185485
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	4830,083092	1207,520773	25,49667769	8,6694E-06
Residual	12	568,3191142	47,35992618		
Total	16	5398,402206			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-4,843153478	4,082010997	-1,186462624	0,258398915	-13,73709126	4,050784302	-13,73709126	4,050784302
Share price-strike	-0,449680769	0,046280618	-9,716395098	4,88269E-07	-0,550517572	-0,348843967	-0,550517572	-0,348843967
Time to mat.(years)	-0,434636725	1,696524574	-0,256192413	0,802141425	-4,13104617	3,26177272	-4,13104617	3,26177272
In/out of the money	5,133703573	4,811855731	1,066886428	0,307017591	-5,350429249	15,6178364	-5,350429249	15,6178364
Market value	0,714037121	1,00629192	0,709572547	0,491527269	-1,478484587	2,906558829	-1,478484587	2,906558829

Market to B-S ratio (with average implied volatility) as depending variable. Option's market value, share minus option's strike price, option's time to maturity and in/out-of-the-money factor as defining variables.